20

HEAT CAPACITY OF FISH MUSCLE: LATENT AND SPECIFIC HEATS

No. 20.

G. O. LANGSTROTH B. A.

HALIFAX, 1928

BIOLOGICAL BOARD OF CANADA

MANUSCRIPT REPORTS OF THE EXPERIMENTAL STATIONS

No. 20

Title

HEAT CAPACITY OF FISH MUSCLE: LATENT AND SPECIFIC HEATS

Author

G. O. LANGSTROTH B. A.

HALIFAX, 1928

BIOLOGICAL BOARD OF CANADA

Manuscript Reports of the Experimental Stations

No. 20

Heat Capacity of Fish Muscle: Latent and Specific Heats

By G. O. Langstroth B. A.

In refrigeration problems it is important to have at hand data on the different aspects of heat transfer. Accordingly values were obtained for the heat capacity of various fish, from which it is possible to find the specific heat, the latent heat and the freezing point. The fish examined were Haddock, Burbot, Brook Trout, Skate, Herring and Cod. Certain differences were found in the above mentioned constants for the different fish.

Apparatus

The apparatus used was a Richards adiabatic calorimeter of the usual type. The outer bath temperature could be adjusted to 0.0008°C. i.e. this amount gave a deflection of one millimeter on the scale. The bath temperature was read from a Beckmann to 0.001°, and was used in finding the rise, or fall, of temperature of the water in the calorimeter only. The absolute bath temperature was measured with a tenth degree thermometer. The calorimeter proper was a copper vessel capable of holding 600 grams of water. Stirring was accomplished in the bath by means of four propeller shaped wheels rotated by a motor, and in the calorimeter proper by a simple "up - and - down" stirrer.

The bath in which the fish was brought to the required initial temperature was placed very close to the calorimeter to facilitate transfer. It consisted of water for the temperatures above the freezing point, of salt and ice from the freezing point down to about -13°, and carbon dioxide and ether below this temperature. Stirring was accomplished by means of an air bubbler. The temperature was read from a tenth degree thermometer down to -13°, and below this with a one degree thermometer.

The fish was contained in a copper container having a screw top, and weighing about 13 grams. The weight of the fish was in general about 10 grams. Its initial temperature was controlled to a tenth of a degree in the auxiliary bath.

Procedure

The heat capacity curve for the container was first obtained by making several runs with it empty. The fish sample frozen was first put in the container and weighed. It was then kept at the desired initial temperature in the auxiliary bath for at least one hour, and in cases in which the temperature was near the freezing point, for two hours. This time was proved ample by preliminary experiments in which the time was changed. Since the fish apparently supercools very easily it was kept in cold storage at a temperature of about -17°C.

In making a run, the temperature of the water in the calorimeter was adjusted so that the final temperature would be as near as possible to twenty degrees. The calorimeter was them put in the bath and the bath brought to the same temperature. When the sample of fish in the auxiliary bath had remained there long enough, the temperature of the outer bath was brought exactly to the temperature of the water in the calorimeter, and the Beckmann was read. When this reading was constant to 0.002° for a period of ten minutes the reading was taken as the temperature of the water in the calorimeter. The fish was then transferred as quickly as possible without touching anything, through the reaction tube. Any heat loss in transfer is largely corrected for by the subtraction of the heat capacity of the container from the heat capacity of the container and fish.

The temperature change in the calorimeter was then followed as closely as possible with the water in the outer bath, the difference being, in the large initial change about 0.5°, but this was brought down very quickly to about 0.02°. Thus heat transfer to, or from, the room was negligible.

When the temperature of the outer and hence of the inner bath was constant to 0.002° for a period of at least ten minutes, as shown by the Beckmann, the run was considered as finished. The end temperature was measured to 0.1° with a tenth degree thermometer in the outer bath. All runs were corrected to twenty degrees in the usual way, a rough value of the specific heat having been calculated.

An analysis for water and for fat was carried out, the results of which were to be more or less expected from the heat capacity curves. The methods will be discussed separately.

The low temperature thermometer was calibrated at the ice point, and at the carbon dioxide (solid) point. The Beckmann was calibrated against a secondary standard, and all others were calibrated against a tenth degree secondary standard.

Discussion

The heat capacity curves are shown in Fig. I. It is evident that different fish have different heat capacity curves, but only below the freezing point. It is also evident that different fish of the same species have slightly different latent heats but the same specific heats as shown by the Herring and the Burbot curves. In all Haddock and Cod curves which were made with fish caught early in the summer, no differences were found, although several different fish were used.. A Haddock caught in the late months of summer however showed a latent heat about three calories less than the early specimens. With the above mentioned exceptions the cod and haddock curves coincide within the limit of experimental error. The freezing points, and the latent and specific heats are given in Table 2.

The results obtained are good to about 1% for the samples examined. The latent heats as given by the curves will not apply that closely to all fish of the same species because of the very noticeable variation in the heat capacity curves for different samples of the same kind of fish. Since all curves for the same species have the same slope their specific heat is the same for all fish of any one kind. It is good to about 1.5% from 0° to 60°, and about 15% for the various single points between -10° and -20°, etc.

The apparent relation between the water content and the latent heat is very noticeable and suggests that the latent heat is almost entirely dependent on the amount of water present. With this assumption it is interesting to note that the heat capacity curves lie in the order expected from a consideration of the osmotic pressure.

Results

The following tables give the results of the heat capacity measurements.

SKATE Samples from one fish only.

Temperature	Heat capacity cal./gm.
61.0	36.4
20.0	0.0
0.0	-16.9
0.0	-17.5
-2.0	-25.3
-2.8	-36.2
-4.8	-59.7
-6.0	-64.5
-8.0	-70.9
-11.0	-76.4
-11.6	-78.0
-12.7	-79.7
-23.3	-83.8
-20.0	-84.2
-41.7	-96.4

BROOK TROUT Samples from three fish.

Temperature	Heat cap. cal./gm.
60.8	36.1
50.3	26.8
40.5	18.0
0.0	-22.0
0.0	-20.7

BROOK TROUT Samples from three fish. (ctd.)

Temperature	Heat capacity cal./gm.
-0.7	-26.2
-1.4	-43.3
-3.1	-65.5
-6.3	-72.4
-6.4	-72.8
-9.8	-78.8
-11.7	-80.2
-13.0	-81.4

BURBOT Samples from two fish.

51.5	28.2
0.0	-18.1
-1.1	-41.1
-1.1	-43.0
-1.7	-53.7
-4.9	-75.0
-7.5	-79.7
-10.0	-82.1
-13.0	-83.5
-13.5	-84.3
-23.8	-89.6
-38.5	-98.1

Second fish	Temperature	Heat capacity cal/gm
	-1.3	-43.8
	-5.5	-77.2
	-10.8	-83.7
	-12.4	-84.8
	-12.8	-85.9

For haddock the results obtained were as follows.

Temperature	Heat capacity
60.7	36.4
50.2	26.8
40.2	17.9
0.0	-16.9
0.0	-16.9
0.0	-18.1
-0.5	-20.2
-1.0	-41.3
-1.3	-41.3
-2.0	-50.9
-2.2	-52.4
-4.2	-69.5
-4.5	-71.0
-4.6	-69.9
-4.6	-69.5
-6.4	-75.8
-6.8	-77.1
-10.5	-80.2
-10.5	-80.0

Temperature	Heat capacity	
-12.8	-82.6	
-14.2	-82.5	
-43.2	-94.0	*
-41.7	-94.0	*
-11.2	-78.5	*
-11.8	-78.5	*

* The fish marked thus were caught later in the summer than those with which the original readings were made. The values thus obtained are somewhat lower in their latent heat than the original ones.

The above values were made with samples from three different fish and no discrepancy is noticeable between them, as is the case with Ling and Herring.

The values obtained for Cod by Dr. Chipman follow the Haddock curve. They are as follows.

Temperature	Heat Capacity
70.0	42.8
70.0	42.2
30.0	10.0
10.0	-9.1
10.0	-9.7
0.0	-17.4
0.0	-18.3
-1.0	-18.6 *
-1.0	-36.2
-2.0	-19.6 *
-2.0	-60.0
-3.0	-20.8 *
-4.0	-21.5 *
-5.0	-72.3
-5.0	-70.5

Temperature	Heat Capacity
-10.0	-81.0
-10.0	-80.5
-20.0	-86.5
-20.0	-86.4
-30.0	-93.3
-40.0	-98.9
-50.0	-103.0
-60.0	-107.8
-70.0	-110.7
-70.0	-111.7

*These values are the result of super-cooling. In all other determinations this was avoided by keeping the sample in the cold storage room, introducing it to the cold temperature bath while frozen, and allowing it to come to the desired temperature.

HERRING Two samples of fish used.

Temperature	Heat Capacity
61.1	35.8
0.0	-17.1
-1.4	-36.2
-3.2	-58.6
-6.6	-71.1
-10.2	-74.2
-12.7	-77.8
-24.9	-82.5
-42.5	-87.9
-42.3	-87.4

With the second sample of fish the following values were obtained.

Temperature	Heat Capacity
-1.6	-32.2
-3.0	-51.4
-7.2	-67.1
-10.1	-72.4
-12.9	-73.5

The above two fish were caught in the middle of July, and both were very fat as the fat analysis shows. However the water content was lower than any of the other fish examined and this probably accounts in a large extent for the low latent heat of herring.

The latent heats, specific heats, and the freezing points as obtained from the curves are given below. The freezing point is obtained from an extrapolated curve, and therefore is good only to 0.2°C. The latent heat is the difference between the heat capacity at the freezing point and the point at which the curve straightens out. The specific heat is obtained in the usual manner.

Fish	Latent Heat	Specific Heat		Freezing Pt.
Haddock	63 cal/gm.	0.0 to 60	0.89	-0.8°C.
		-10 to -20	0.70	
		-20 to -30	0.63	
		-30 to -40	0.56	
Cod	ditto	ditto		ditto
Skate	60 cal/gm.	0 to 60	0.89	-1.8°
		-20 to -30	0.63	
		-30 to -40	0.56	
Herring	57 cal/gm.	0 to 60	0.89	-1.0°
	54 cal/gm.	-10 to -20	0.63	
		-20 to -30	0.40	
		-30 to -40	0.26	
Burbot	64 cal/gm.	0 to 60	0.89	-0.7°
	65 cal/gm.	-10 to -20	0.68	
		-20 to -30	0.63	
		-30 to -40	0.56	
Brook Trout	62 cal/gm.			-0.8°

Water Analysis

A water analysis of the fish samples was carried out in two different ways; one by the use of a vacuum dessicator and t the other by passing dry air over the sample heated to about 105°C. The first of these is probably the better method since in the latter there may be some of the oils or fats volatilized and carried off with the water vapor.

The vacuum dessicator was of the usual type. Concentrated sulphuric acid was used as a dryer. About eight grams of the fish, finely sliced, were used in one determination. The samples was allowed to dry for a day and a half and weighings were made every hour and a half. When these were constant to 0.004 gms the run was considered as finished.

In the other method the fish was placed in a small flask, which was immersed in a salt solution at 105°C. Air dried by passage over concentrated sulphuric acid was passed over it, and then passed through more sulphuric acid, so that if any appreciable amount of organic substance was liberated by heating, it would discolor the acid. This formed a very rough check on the liberation of organic substances. It was found that there was only a very slight discoloration, and hence it was concluded that only water vapor was being given off to any extent.

Unfortunately samples from the same fish as used in the heat capacity measurements were not always obtainable. All analyses were made, however with samples from fish caught at the same time, and passing through the same handling as the investigated fish. The results are given below.

BURBOT

Samples from fish used in determinations.

82.8 %	Mean value 83 %
83.5 %	

HADDOCK

Samples from a fish not used in determinations

80.3 %	Mean value 80%
79.1 %	

COD

Samples not used in determinations.

79.9 %	Mean value	80 %
80.4 %		

SKATE

Samples used in determinations.

78.6 %	Mean value	79 %
80.6 %		

HERRING

Samples used in determinations

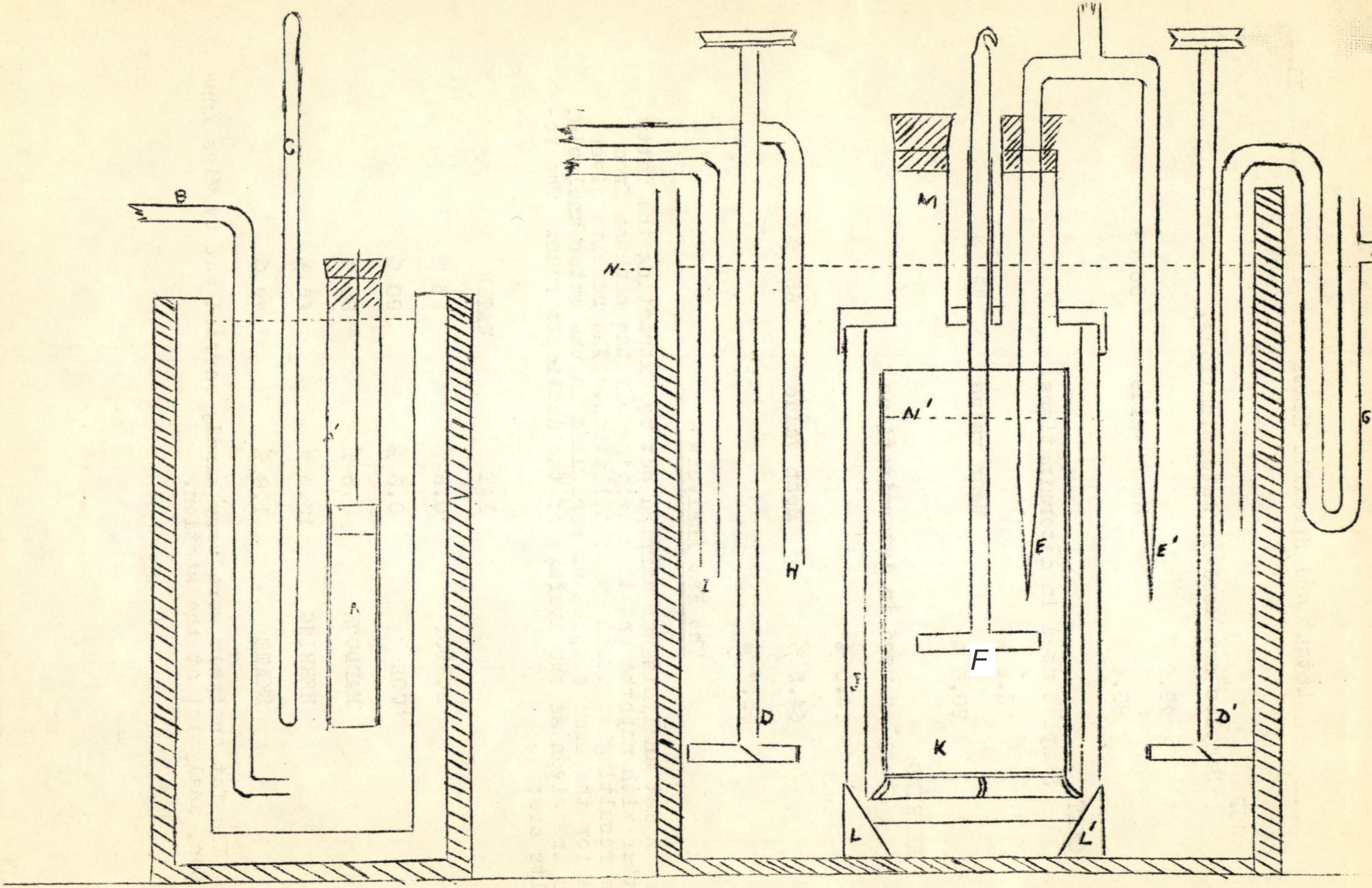
64.0 %		
64.5 %	Mean value	65 %
65.7 %		

The Fat Analysis

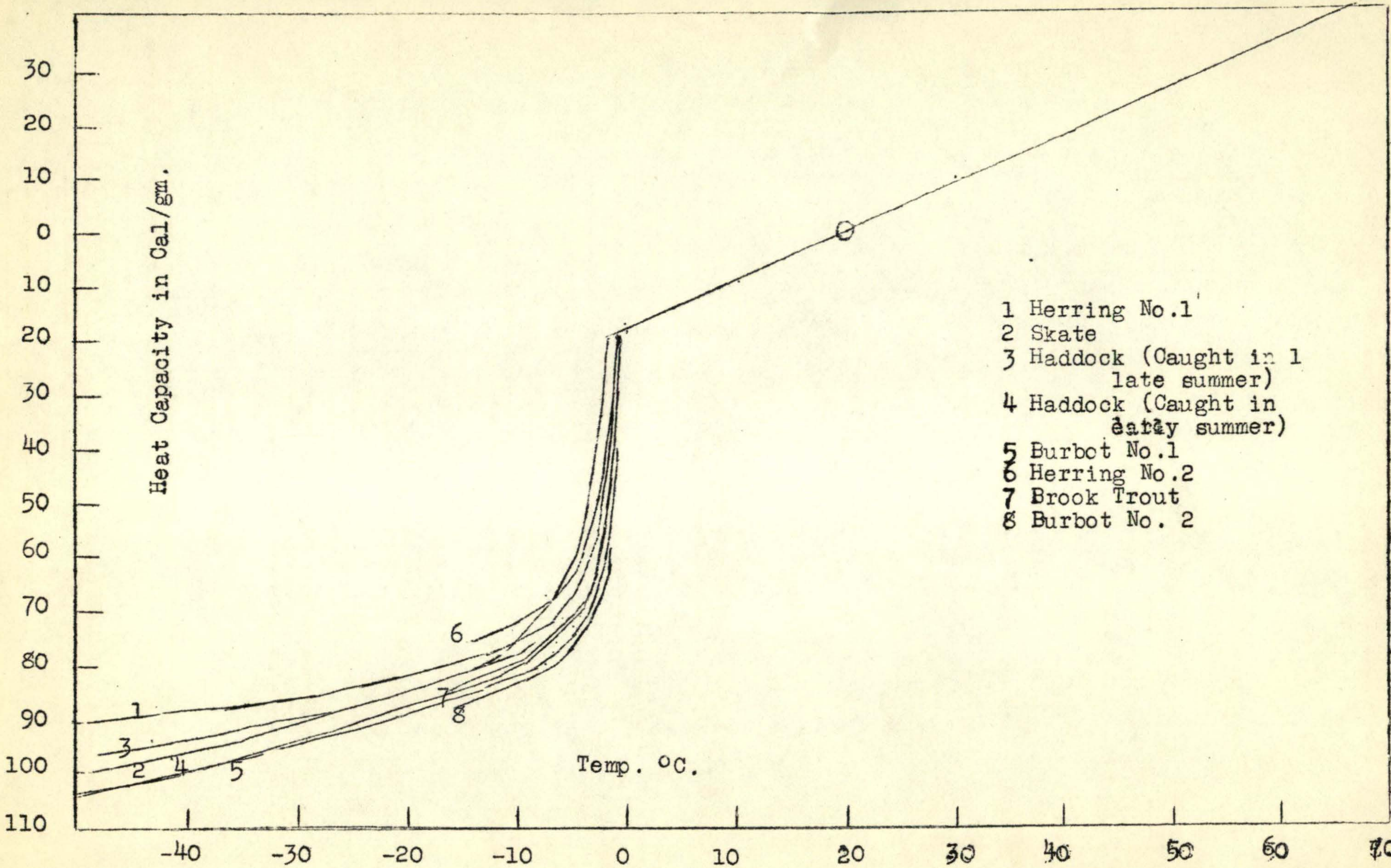
A fat analysis was carried out by extracting the fatty matter with naphtha and then driving off the naphtha from the resulting solution by distillation. The results given are for the same samples as were used in the water analysis, and are given as the average of two duplicate runs. The results are;

	FAT	WATER
BURBOT	0.6 %	83 %
COD	0.3 %	80 %
HADDOCK	0.3 %	80 %
HERRING	13.3 %	65 %
SKATE	1.8 %	79 %

The fat analyses were very kindly carried out by Miss Anna Wilson, analysisist at the station.



A	Fish Container	D,D'	Rotational Stirrers	H,I,	Cold and Hot Water Inlets	M	Reaction Tube
A'	Copper Tube	E,E'	Thermo Couple	J	Calorimeter Bomb	N	Water Level in bath
B	Bubbler Tube	F	Stirrer	K	Calorimeter Proper	N	Water level in Cal.
C	Thermometer	G	Siphon Overflow	L,L'	Bomb Supports		



Heat Capacity in Cal/gm.
30
20
10
0
10
20
30
40
50
60
70
80
90
100
110
Temp. °C.
-40
-30
-20
-10
0
10
20
30
40
50
60
70
1 Herring No.1
2 Skate
3 Haddock (Caught in late summer)
4 Haddock (Caught in early summer)
5 Burbot No.1
6 Herring No.2
7 Brook Trout
8 Burbot No. 2
1
2
3
4
5
6
7
8